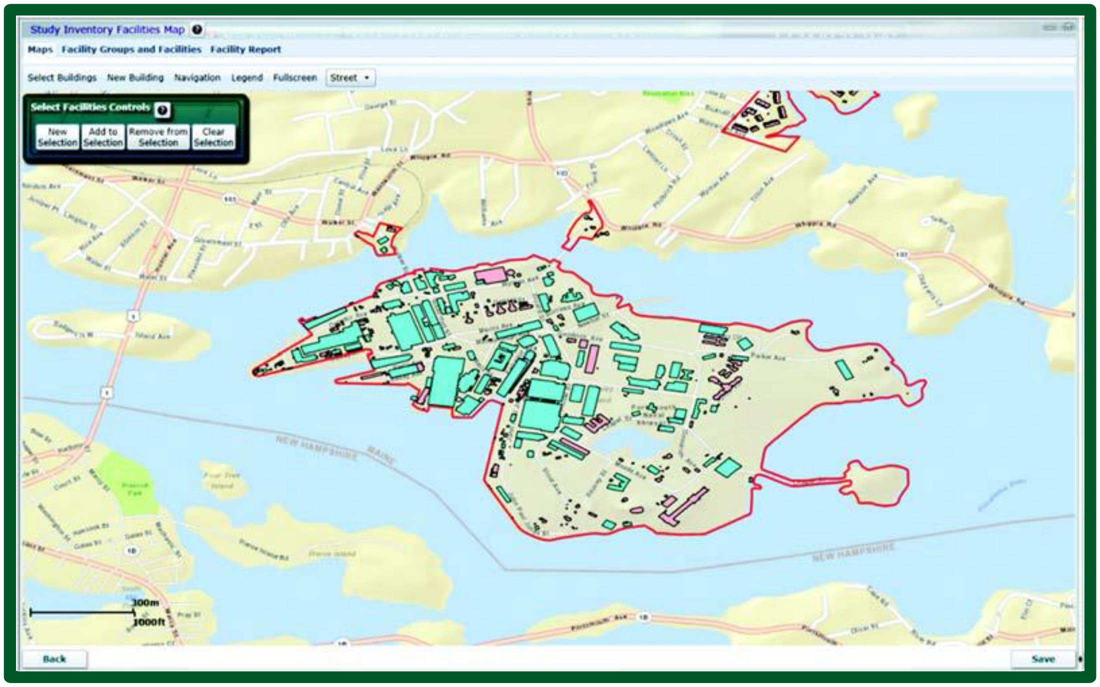
ESTCP
Cost and Performance Report

(EW-201240)



Demonstrate Energy Component of the Installation Master Plan using Net Zero Installation Virtual Testbed

November 2015

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Alexander M. Zhivov, Michael. P. Case, Richard. Liesen, and Mathew Swanson.

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Research and Development Center (ERDC)
Construction Engineering Research Laboratory (CERL)
PO Box 9005
Champaign, IL 61826-9005

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14. ABSTRACT
This work demonstrated the energy master planning (EMP) concept and automated Net Zero Planner tool (NZP) developed by the Army Engineer Research and Development Center (ERDC) at two U.S. Department of Defense (DoD) installations: United States Military Academy, West Point (USMA) and Portsmouth Navy Shipyard (PNSY). The NZP Tool incorporates the concept and various automated modules to integrate optimization across buildings, distribution, and generation systems. Results demonstrated that use of the NZP Tool reduces the time required for the analysis and the analysis cost to ~35% of the time required by the alternative current best practice. Lessons learned from the project were used to make many user interface changes were made throughout the program to facilitate the process, to ease data entry, and to help determine the information required to produce useful, relevant output reports. Funding for this demonstration was provided by the Environmental Security Technology Certification Program (ESTCP) - Energy and Water Project # EW-201240.

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Central Energy Plant, Deep Energy Retrofit, Energy Policy Act, Energy and Water, Energy Use Intensity, Greenhouse Gas, Geographic Information System, Gas Turbines, HVAC, Liquefied Natural Gas, Photovoltaic, Sustainability Component Plans, Sustainment, Restoration and Modernization

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TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

Page

LIST OF TABLES

Page

ACRONYMS AND ABBREVIATIONS

ADP	Area Development Plan
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BLCC	Building Life Cycle Cost
CAC	Common Access Card
CBECS	Commercial Buildings Energy Consumption Survey
CEP	Central Energy Plant
CERL	Construction Engineering Research Laboratory
CHP	Combined Heat and Power
DD	Dry Dock
DER	Deep Energy Retrofit
DHW	Domestic Hot Water
DoD	U.S. Department of Defense
DPW	Directorate of Public Works
ECBCS	Energy Conservation in Buildings and Community Systems
EEM	Energy Efficiency Measure
EISA	U.S. Energy Independence and Security Act of 2007
EMP	Energy Master Planning
EPAct	Energy Policy Act
ERDC	Engineer Research and Development Center
ESPC	Energy Savings Performance Contract
ESTCP	Environmental Security Technology Certification Program
EUI	Energy Use Intensity
EW	Energy and Water
FY	Fiscal Year
GFEBS	General Fund Enterprise Business Systems
GHG	Greenhouse Gas
GIS	Geographic Information System
GT	Gas Turbines
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HVAC	Heating, Ventilating, and Air-Conditioning
HW	Hot Water
IEMP	Integrated Energy Master Planning
IRR	Internal Rate of Return

LCC	Life Cycle Cost
LNG	Liquefied Natural Gas
MBtu	Thousand British Thermal Unit
MCDA	Multi-Criteria Decision Analysis
MILP	Mixed-Integer Linear Programming
MMBtu	Million British Thermal Unit
MW	Megawatt
NAVFAC	Naval Facilities Engineering Command
NIST	National Institute of Standards and Technology
NZE	Net Zero Energy
NZI-OPT	Net Zero Installation Optimization
NZP	Net Zero Planner
OASA	Office of the Assistant Secretary of the Army
PNSY	Portsmouth Naval Shipyard
PV	Photovoltaic
RECs	Renewable Energy Credits
RECS	Residential Energy Consumption Survey
SCP	Sustainability Component Plans
SDSFIE	Spatial Data Standards for Facilities, Infrastructure, and Environment
SME	Subject Matter Expert
SPB	Simple Payback
SRM	Sustainment, Restoration, and Modernization
UFC	Unified Facilities Criteria
USACE	U.S. Army Corps of Engineers
USMA	U.S. Military Academy
WPMA	West Point Military Academy
XML	Extensible Markup Language

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The Project Working Team appreciates the support and advice provided by the ESTCP review board through the process of development of the demonstration plan; cooperation from the USMA and Portsmouth Navy Shipyard (PNSY) personnel team members and USACE New York District engineers, ideas and information shared by researchers and engineers from the National Renewable Energy Laboratory, Sandia National Laboratory, and NORESCO company. A wealth of knowledge and information was provided by the partners from the International Energy Agency Energy Conservation in Buildings and Community Systems (ECBCS) Program Annex 51 "Energy Efficient Communities" throughout development of this project.

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EXECUTIVE SUMMARY

OBJECTIVES OF THE DEMONSTRATION

The objective of this project was to demonstrate a holistic Energy Master Planning (EMP) concept and the Net Zero Planner (NZP) Tool at two defense installations: the U.S. Military Academy (USMA) at West Point, NY, and the Portsmouth Naval Shipyard (PNSY), Kittery, ME. The demonstration was designed to test whether the implementation of this concept and tool together would reduce the time and cost of conducting an energy planning process in pursuit of Department of Defense (DoD) energy goals, compared to working without the tool. Such goals may include achieving Net Zero Energy (NZE) in a way that meets or exceeds the Energy Policy Act (EPAct) (2005) and U.S. Energy Independence and Security Act (EISA) (2007) criteria for energy intensity, that meets energy security requirements at a lower cost, and that controls electrical capacity growth requirements. If the tool could be demonstrated to reduce the time and cost of planning, then deployment of such a tool, together with a dissemination of lessons learned through pilot EMPs, would support achievement of DoD's mid- and long-term energy goals.

TECHNOLOGY DESCRIPTION

The U.S. Army Engineer Research and Development Center (ERDC) has developed an Integrated Energy Master Planning (IEMP) concept and the automated Net Zero Planner (NZP) Tool to support U.S. DoD energy policy. The energy concept minimizes energy use at the building level, improves the efficiency of energy conversion and distribution, and uses energy from renewable sources to balance fossil fuel based energy to achieve a net zero fossil fuel energy status. Energy goals are achieved through synergy among energy use reduction in building-related systems, energy supply, and distribution systems. The NZP Tool incorporates the concept and various automated modules to integrate optimization across buildings, and their energy generation and distribution systems. Figure ES-1 shows the planning process applied in the NZP Tool.

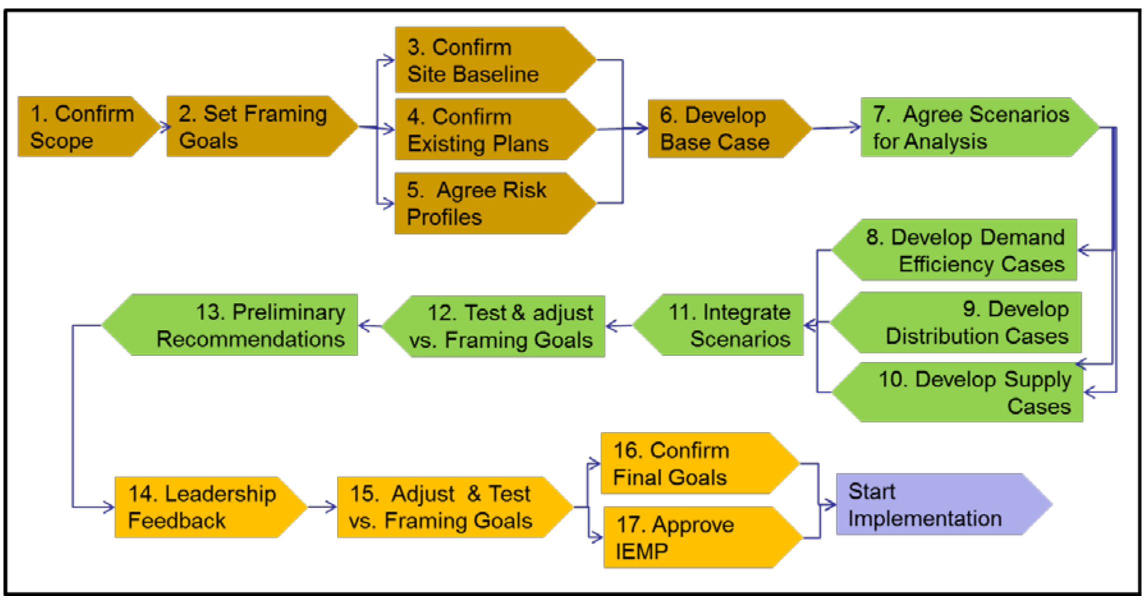

Figure ES-1. The IEMP Process Overview.

DEMONSTRATION RESULTS

Several alternative scenarios were analyzed, including building energy efficiency improvements, decentralization of energy conversion systems, conversion from steam to hot water distribution systems, trigeneration, and energy supply from renewable sources. Analyses conducted for the USMA showed that, despite additional loads due to new construction and a new requirement for cooling in barracks, all analyzed scenarios, the Base Case, and four alternatives would significantly reduce energy use. Compared to the Baseline, the alternatives reduced energy use from 31 to 51% for site energy and from 27 to 84% for source energy, and they reduce energy costs from 27 to 84%. NZE status for the selected area can be achieved by switching from natural gas to syngas in the future if its cost becomes comparable with that of natural gas.

For PNSY, the reduction of building and process loads with Energy Efficiency Measures (EEMs) and the reduction of distribution and conversion losses were not enough to cost-effectively meet the installation's energy goals. Navy installations can purchase Renewable Energy Credits (RECs), but PNSY leadership expressed a preference for not exercising that option to attain the targets. At both installations, the NZP Tool method and Subject Matter Expert (SME) manual method showed very similar modeling results at the building loads step of the process, and they also showed the same trends in Life Cycle Cost (LCC) when conversion alternatives were compared.

The investment cost and energy usage results for both methods were generally within 10–20% of each other for all the scenarios, despite the differences in the process used in each method. Furthermore, the energy usage and investment cost rankings, which were the same for both groups, ultimately resulted in the same recommendations for both installations.

A comparison of a budget allocated to conduct the energy analysis manually (using the two groups of SMEs and time and labor cost of ERDC researchers) with a budget to conduct a similar analysis using the NZE Planner Tool, showed that the application of the NZP Tool costs about 20% of the cost of the alternative (manual) method.

IMPLEMENTATION ISSUES

The EMP concept and the NZP Tool were refined during the project, including the introduction of a "Baseline" (current situation) and a "Base Case" (future situation under a business as usual scenario). Procedures for calibration of the Baseline and Base Case using utility bills and data from energy meters became an important step in the beginning of the study. There was a need to define installation-specific energy goals, which establish the type of study that needs to be performed, i.e., a planning or pre-engineering analysis. Two groups of users were determined, each with different output requirements. Installation master planners have a need for NZP, which helps to provide a Sustainability Component Plan to overlay their Master Plans. The Sustainability Component Plan is a new concept that Corps of Engineers have begun using to add energy implications to Master Plans. The other identified user is the installation energy manager; whose need is for help in identifying and sequencing coordination of projects, which requires a pre-engineering assessment. Other technical changes were incorporated throughout the Tool as defined by the user's needs and requirements; for example,

- Energy goals were added to the decision model to clarify and focus on customer program intents.

- Login and installation security were added.
- Speed and performance upgrades were made.
- Reporting capabilities were added, e.g., peak demands, source energy, site source conversions.
- Costing capabilities were added, e.g., detailed costing for the building and installation.
- Installation and plant device data (net-zero installation optimization [NZI-OPT]) were expanded to account for equipment at legacy steam systems.
- Thermal Network Analysis and Photovoltaic (PV) Solar Data were augmented to allow needed steam or Hot Water (HW) systems to have data to determine the modeled performance for an integrated solution.
- A Multi-Criteria Decision Analysis (MCDA) tool was integrated to help quantify data and perform a qualitative analysis in a quantitative decision tool.

Another area of the analysis directly affected by the ESTCP project was the reporting for buildings, and for supply and distribution sections. One of the reports that was added was the Multi-Criteria Decision Analysis report, which helps rank alternative solutions. This report was related to the energy goals described in the study details tab and was directly associated with the decision model for the study.

The U.S. Army Corps of Engineers (USACE) or Directorate of Public Works (DPW) typically either develops Installation Master Plans in-house, or subcontracts the development to private sector companies. NZP can be used either by in-house personnel or by contractors. The limited number of USACE energy master planners can easily be trained to apply EMP concepts and use the NZP Tool. However, all potential contractors involved in EMP would require training to make effective use of NZP. An initial training course, which was developed and delivered to the PNSY planners and energy manager in November 2014, was instrumental in creating a course for USACE personnel that was offered in January 2015. NZP course material derived from these courses has been integrated into the USACE PROSPECT Sustainability Course.

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1.0 INTRODUCTION

Until very recently, defense installation planners addressed energy systems for new facilities and facilities undergoing renovation on an individual facility basis without consideration of energy sources, renewables, storage, or future generation needs. Building retrofits under Sustainment, Restoration, and Modernization (SRM) projects typically do not address energy conservation. Energy Savings Performance Contract (ESPC) projects that address only "low hanging fruit" (improved efficiency of lighting, electrical, heating, ventilating, and air-conditioning [HVAC] systems, controls, and Building Energy Management Systems [BEMSs]) will fail to maintain the current rate of energy reduction, let alone meet the rate required by U.S. Energy Independence and Security Act of 2007 (EISA 2007), and will thereby become less economically attractive. Most utility modernization projects executed at Department of Defense (DoD) installations focus on repairing or replacing distribution and energy conversion systems in-kind, or on decentralizing energy systems by abandoning aging steam distribution systems. In community-wide energy planning, it is important to consider the integration of supply and demand, which leads to optimized solutions. This demonstration was undertaken to apply the principles of a holistic approach to community energy planning and to provide the necessary (and previously unavailable) methods and instruments to master planners, decision makers, and stakeholders.

1.1 BACKGROUND

The U.S. Army Engineer Research and Development Center (ERDC) has developed an Energy Master Planning (EMP) concept and automated Net Zero Planner Tool (NZP) (Case et al. 2014) to support DoD energy policy. The energy concept minimizes energy use at the building level, improves the efficiency of energy generation and distribution, and uses energy from renewable sources to balance fossil fuel based energy to achieve a net zero fossil fuel energy status. Energy goals will be achieved through synergy among energy use reduction in building-related systems, energy supply, and distribution systems. NZP integrates these interrelated components with various automated tools to optimize energy use across buildings, distribution, and generation systems.

1.2 OBJECTIVE OF THE DEMONSTRATION

This project successfully met its objective, to demonstrate a holistic EMP concept and NZP at two defense installations, the U.S. Military Academy (USMA) at West Point, NY, and the Portsmouth Naval Shipyard (PNSY), Kittery, ME. The implementation of this concept and tool will enable a streamlined energy planning process that allows users to develop an executable roadmap to meet or exceed installation energy goals at the lowest lifecycle cost. Such goals may include achieving Net Zero Energy (NZE), meeting or exceeding EPAct (2005) and EISA (2007) criteria for energy intensity, meeting energy security requirements at a lower cost, and controlling electrical capacity growth requirements.

1.3 REGULATORY DRIVERS

Federal government agencies are required by law to eliminate fossil fuel use in new and renovated facilities by 2030 and to reduce overall facility energy usage by 30% by 2015 (EISA 2007).

New buildings and buildings undergoing major renovations are required to reduce consumption of fossil fuel-generated energy, both off- and onsite, as compared with energy consumption by a similar building in fiscal year 2003 (FY03) (as measured by Commercial Buildings Energy Consumption Survey (CBECS 2003) or Residential Energy Consumption Survey (RECS 2003) data from the Energy Information Agency) — by 55% in 2010, 80% by 2020, and 100% by 2030.

The 2005 Energy Policy Act requires that federal facilities be built to achieve at least a 30% energy savings over the 2004 International Energy Code or American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 90.1-2004 (ASHRAE 2004), as appropriate, and that energy efficient designs must be Life Cycle Cost (LCC) effective. In April 2011, the U.S. Army selected eight pilot installations to achieve NZE by 2020 (EISA 2007). In January 2014, the Secretary of the Army issued the Net Zero Installations Directive, which expanded the Net Zero Initiative beyond the pilot installations to all permanent Army installations. The U.S. Navy is also selecting several installations to achieve NZE goals.

Other significant drivers relevant to energy efficiency in DoD and other Federal buildings include:

- Federal Leadership in High Performance and Sustainable Buildings. Memorandum of Understanding of 2006,
- Executive Order 13423 Strengthening Federal Environmental, Energy, and Transportation Management of 2007,
- Unified Facilities Criteria (UFC) 3-400-01 Energy Conservation, with changes of 2008,
- Army Energy Security Implementation Strategy of 2009,
- Executive Order Executive Order 13514—Federal Leadership in Environmental, Energy, and Economic Performance of 2009,
- Office of the Assistant Secretary of the Army (OASA) Memorandum: Sustainable Design and Development Policy Update (Environmental and Energy performance) of October 2010.

To become low/net zero energy, installations must implement aggressive conservation and efficiency efforts with new construction and existing building stock, reduce waste and inefficiency in energy generation and distribution systems, and meet the balance of energy needs from renewable energy sources. Such an approach requires integrated EMP. DoD Instruction 4165.70 (Real Property Management) establishes the requirement for Installation Master Plans. Unified Facilities Criteria (UFC) 2-100-01 (HQUSACE, NAVFAC, and AFCESA 2012) prescribes minimum DoD requirements for master planning, with integrated EMP being a part of the Area Development Plan (ADP) process.

2.0 TECHNOLOGY DESCRIPTION

2.1 TECHNOLOGY OVERVIEW

Both the EMP process and the NZP Tool technology can be taught to energy Subject Matter Experts (SMEs). Once the study is completed, there will be an installation energy model that can be modified and maintained by the installation with relatively little effort. Unlike a paper report, study models can be easily copied and updated as circumstances change.

Energy planning may be conducted at varying levels of detail, depending on the purpose of the planning exercise. Figure 2-1 shows the level of detail used at various installations. Traditional engineering studies require more in-depth analysis and costing (the right-hand side); Sustainability Component Plans (SCP), conducted as a part of Real Property Master Planning process, require less detail (the left-hand side). The studies conducted for this project fall somewhere in the middle, with more detailed analysis and costing. NZP is meant to be used at the planning level, where a holistic-integrated plan is needed. The following sections discuss the definitions of goals and objectives, the identification of system boundaries, and the creation of a road map for implementation.

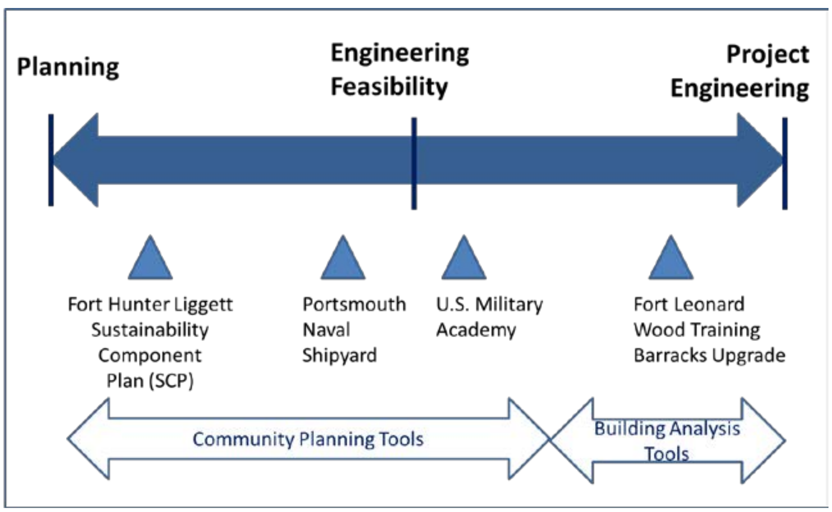

Figure 2-1. Energy Planning Exists on a Continuum, Increasing in the Required Level of Detail from Left to Right.

2.1.1 Establish Scope and Boundaries

The scope of the energy minimization effort can include residential, commercial, and public buildings; community-based infrastructure; industrial energy users; community-owned and transit transportation; and other energy-consuming users; or any combination of those. A community can have fixed boundaries defined either by physical limitations (e.g., an island-based community) or political or administrative boundaries. An analysis of community boundaries may also reveal how communities can best meet their energy needs (e.g., by purchasing power, hot water, steam, chilled water, or other utilities from networks, and/or by capturing waste heat from processes). The same analysis can determine the feasibility of exporting power, heat, and cooling energy from cogeneration to other buildings within the community.

The Net Zero Planner is web-based. Important information for all military installations can be found on a centralized database and Geographic Information System (GIS) server. The system is currently only accessible to users through a *.mil domain address. Analysis starts with the selection of the military installation using the initial screen (Figure 2-2). Users select the geographic scope of the analyzed installation or its part by choosing the area within an installation boundary (Figure 2-3). NZP has boundaries for all Army installations and several Navy and Air Force installations.

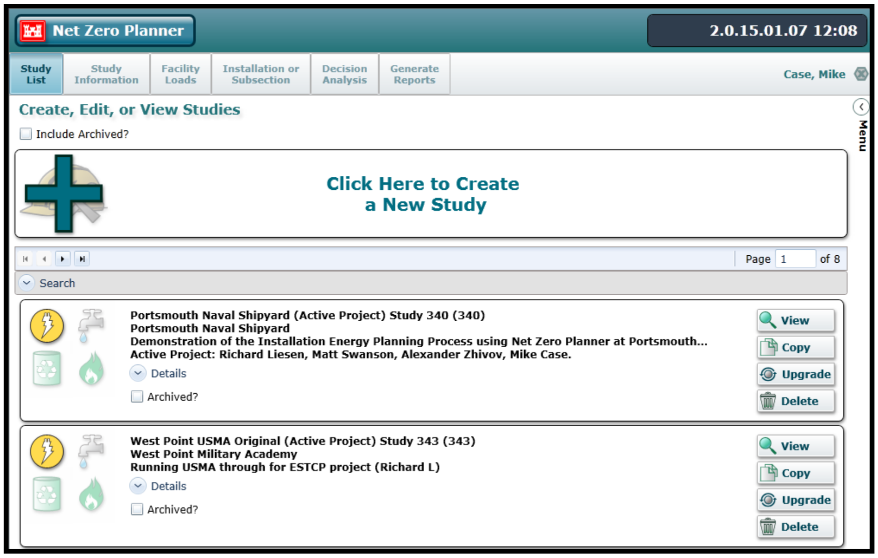

Figure 2-2. NZP is a Web-based System. This Screen Shows a List of Studies to which the User has Access.

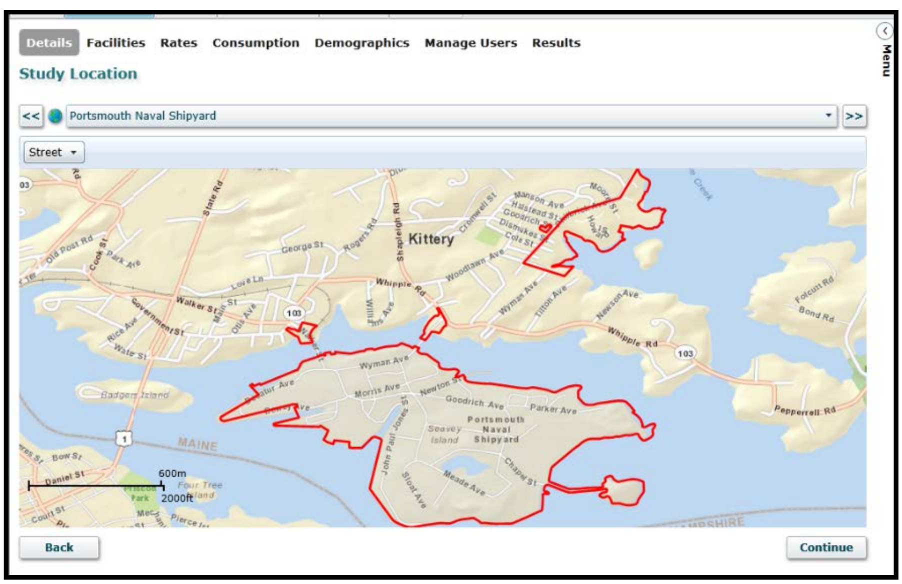

Figure 2-3. Select Geographic Scope of the Study.

Once the installation boundary has been selected, the user chooses the facilities that will be included in the study. These data come from Spatial Data Standards for Facilities, Infrastructure, and Environment (SDSFIE)-compliant GIS, usually obtained from the installation itself. Figure 2-4 shows the selection screen for including buildings and existing infrastructure in a study.

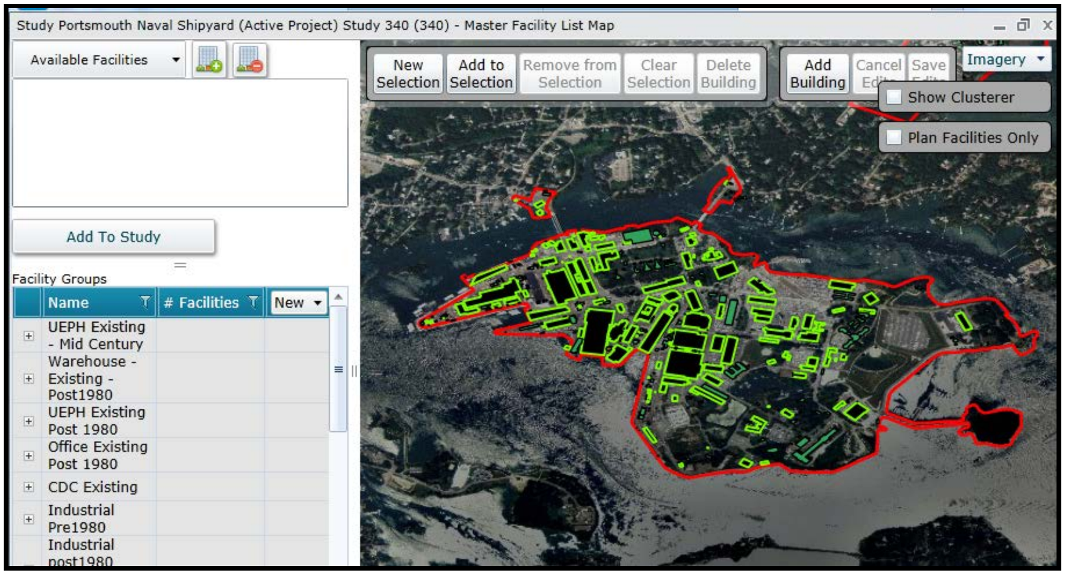

Figure 2-4. The User Selects Facilities to Include in the Study.

2.1.2 Establish Energy Goals

It is important to clearly define long- and short-term energy goals at the beginning of a study, as well as important limitations and other priorities, e.g., energy efficiency, energy supply security, peak power loads, carbon footprint, water availability and conservation goals, etc. It is entirely possible that the goals will turn out not to be feasible, in which case the goals can be adjusted once quantitative data are available. After defining the community energy goals, it is important to connect these goals to the existing community's "core values" and energy-related constraints. Installation/ community leaders, decision makers, and end users and businesses can help to define these core area values and to connect them with the planned installation/community development.

2.1.3 Collect Data

In addition to GIS data on facilities, additional information is needed, including existing facilities, planned facilities, and those planned for demolition. There is usually a "data cleaning" step to ensure that the GIS data entered into NZP is complete and accurate. Trained SMEs are required for this step. Detailed information is needed for a pre-engineering study and more general information is sufficient for a planning study.

2.1.4 Establish Baseline Models and Calibrate Against Metered Data

The importance of the most difficult part of doing an analysis —establishing the *Baseline* energy usage— cannot be over emphasized. The Baseline (site and source energy usage and energy cost) is defined as the current energy consumption profile. It is essential that the Baseline energy use profile capture the quantity and type of energy used (converted by the installation at the central energy plant [CEP] or at individual buildings) such as grid electricity, natural gas, propane, and energy generated from renewable sources (e.g., solar, wind, hydro, etc.). It is also important to understand how the energy is used, whether for heating, cooling, plug loads, or industrial processes.

The Baseline is a snapshot of a point in time and can be derived from a reference year or from consumption data averaged over several years to even out climatic variations.

2.1.5 Establish Base Case

The baseline data described above can be used to project a Base Case scenario for energy use given the availability of information on an increase or decrease of energy use due to: new construction; consolidation and demolishing processes; buildings repurposing and change of mission; use of new and existing utility contracts; and the dates when known contracts will expire. Any planned and programmed measures for energy use reduction through efficiency measures should be included in the Base Case scenario (Case et al. 2014). The Base Case is defined as a future "business as usual" alternative that includes all existing and already planned facilities.

2.1.6 Develop Alternative Scenarios

Once the Baseline and Base Case have been established**,** energy planners can start exploring options or alternative scenarios. A handful of alternative scenarios shall be selected that will be analyzed in depth. Electric and thermal energy systems consist of three major elements: energy generation, energy distribution, and energy demand (Güssing 2011). The goal is to find the optimum balance of these three elements for the entire energy system, where each element is considered in the calculation of the amount of energy delivered and lost, in various forms, by the energy systems (Loorbach 2007).

2.1.7 Conduct Building Level Optimization

It is generally accepted that it is most cost effective to reduce facility loads before exploring distribution and supply options. However, highly efficient central or district plants may change the economics of facility Energy Efficacy Measure (EEMs). To minimize facility energy loads, the user examines the results of applying EEM packages to each facility group. Generally, copies of the Base Case consider the estimated amount of new construction and deep retrofit rate to select the likely level of penetration of EEMs into the building stock. This will give an indication of the most likely reduction in facility loads for the installation.

2.1.8 Develop Load Profiles for Building Clusters

After the LCC efficient bundles of energy efficient measures have been applied to decrease load as much as possible, the analysis continues with distribution and supply systems optimization. The supply system optimization process determines the lowest LCC suite of equipment and ensures that the demands for heat, cooling, and electric energy are satisfied during each of the 8760 hours of the year, and that additional user-specified constraints are also satisfied.

2.1.9 Optimize Installation Conversion, Distribution, and Storage Architecture

Given a set of heating, cooling, and electrical power needs for each cluster, NZP uses mixed-integer linear programming (Swanson et al. 2014) to determine the optimal mix of generation (energy conversion), distribution, and energy storage that meets the installation goals at the lowest cost. Industrial scale supply solutions such as solar photovoltaics, solar-thermal, wind energy, biomass (wood chips, etc.), biogas, or synthetic gas need to be considered as part of the mix during

distribution and supply optimization. Once devices and constraints have been set, Mixed-Integer Linear Programming (MILP) optimizations are run for every cluster in every alternative.

2.1.10 Compare Scenarios

Ultimately, the purpose of the analysis using NZP is to support the client installation in making decisions that, in turn, lead to a well formulated EMP. NZP supports this goal with reports that allow comparing the Baseline, Base Case, and alternatives using the criteria defined as part of the energy goals. There is also a MCDA tool that can be used to create weighted decision models and support traceable decision processes that integrate quantitative and qualitative factor.

2.1.11 Develop Implementation Strategy

An implementation strategy is important once the installation decides on a preferred alternative. Although the NZP tool can provide data to support the strategy (such as a listing of EEM upgrades by facility type as well as supply and distribution equipment) it does not currently provide automated support to generate an implementation strategy. Nonetheless, this is an important follow-on to the EMP process.

2.1.12 Complementary Goals (Spin-Offs, Co-Benefits)

Different innovative NZE projects around the world have shown that energy efficient projects will be more successful if they can be linked to other key issues, which are of an economic, social (quality of life), health, or environmental character. For both military campuses and local communities, energy security and indoor environmental quality (especially in hot and humid climates) become increasingly important spin-offs (Zhivov et al. 2014b; Kimman, Rovers, and Ravesloot 2010). In situations where it is possible to quantify the value of particular spin-offs, its impact on alternative's LCC can be added to the energy-related component.

2.1.13 Implementation Strategy: Backcasting and Forecasting

As a part of an implementation strategy, long-term goals are transitioned into medium-term goals (milestones) and short-term projects, which must have tangible results. It is important to recognize that many decision makers (e.g., installation commanders, etc.) have limited-term assignments or duties and will more likely commit to projects that can be realized during their tenure. Furthermore, short-term projects satisfy the short-term (1 to 5 years) planning process. It is important to get commitment from both decision makers and funding agencies since they play key roles in achieving the long-term goal. The main restriction is that 100% of the short-term projects fit on the roadmap toward the long-term goals.

The transition process is described in terms of the definition and implementation of a roadmap to net zero energy communities. As soon as the long-term goal is set, one can apply backcasting and forecasting techniques to define the process leading toward energy neutrality (Annex 51 2013; Zhivov et al. 2014b; Kimman, Rovers, and Ravesloot 2010). Both backcasting and forecasting approach the challenge of discussing the future from opposite directions. Backcasting and forecasting processes are both necessary to determine the transition path and to make the roadmap as concrete as possible. Both backcasting and forecasting can be used for monitoring the transition process to the long-term goals.

2.2 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

2.2.1 Performance Advantages

The EMP concept and NZP Tool allows for a holistic approach to community EMP. The demonstrated tool is a unique highly-automated software package that can be used for community, or clustered building levels of energy analysis. Grouping buildings by categories and era of construction can be done more quickly using the tool since it has a database with pre-set packages of technologies and different building types' Energy Use Intensity (EUI). This feature comes handy with selection of packages of EEMs for different levels of building energy renovation.

One of NZP's unique features allows calculation of 8760-hour heating, cooling, and power load profiles for all buildings included in the selected building cluster that can account for coincident and non-coincident loads. The load diversification factor varies depending on composition of building types included in the cluster and can reach 0.7 or even be lower. This feature allows for the selection of more accurate energy generation and conversion equipment and for operation based on realistic peaks and more accurate cost estimates for scenarios under consideration.

Another unique feature of the tool is its ability to provide both building-level energy consumption modeling and a cluster-level energy generation and distribution modeling and equipment selection with an easy iteration of building models. For example, if optimization of cogeneration process results in excessive waste heat, energy building level of energy efficiency can be adjusted.

2.2.2 Cost Advantages

Development of an Energy Master Plan requires upfront investment in long-term planning, which can cost up to several hundred thousand dollars. However, these investments can be paid back from savings resulting from implementation of one or few projects implemented under the holistic energy roadmap.

2.2.3 Limitations

Application of the developed EMP concept and NZP Tool require training and experience in EMP. Experience gained through this project shows that such training is required both for better understanding the EMP process and familiarization with its application using the tool. The main barriers/bottlenecks to development of energy efficient installations/communities planning and implementation most commonly occur in the areas of large project financing, holistic project design, and installations' buy-in for deep energy retrofits, procurement, quality assurance, and collaboration between different trades. Bottlenecks are often characterized by short-term thinking, separation of implementation and operation, lack of incentives to achieve energy goals (including a lack of negative consequences for energy inefficiency), segmentation of organizations, lack of coordination between different projects executed within the same organization, etc.

The NZP Tool requires a significant IT infrastructure to set up, primarily due to DoD and Army security requirements (Risk Management Framework), but also due to server and software requirements. Under the current Memorandum of Agreement with Fort Worth District, funds are provided to ERDC to support hosting in the ERDC Cloud Computing Environment, system administration, project data setup, and about 20% towards new features. The target is to minimize these costs as experience is gained. ERDC is also providing training to USACE Districts via web conferencing, consisting of bi-weekly (every 2 weeks) 2 hour sessions. This training will be recorded, and will also leverage tutorial videos developed under ESTCP project #201578-T2. Based on experience, it takes about 40 hours of classroom/web training and 80 hours of shadowing assessors in the field to train an engineer to credibly use NZP.

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3.0 PERFORMANCE OBJECTIVES

The goal of this project was to demonstrate the EMP concept and the NZP Tool at two DoD installations, and through that demonstration, to show that their use enables a streamlined energy planning process that results in a roadmap to meet or exceed the installations' energy goals at a lifecycle cost below that resulting from implementation of the Base Case. The Base Case was developed using the current Master Planning process. The project goal was considered met if the six objectives listed in were achieved.

Table 3-1. Summary of Quantitative Performance Objectives.

Performance Objective	Metric	Data Requirements	Success Criteria	Results
1. Installation/campus-wide source energy use reduction compared to the Base Case	Annual energy use (MMBtu or kWh)	Installation provides electrical and fuel bills	55%	Met at USMA, not met at PNSY
2. Installation/campus-wide energy cost reduction compared to the Base Case	$	Installation provides electrical and thermal energy bills	60%	Met at USMA
3. Electrical peak load capacity	Peak electrical load (MW)	Installation provides projected electrical capacity requirements and contract limitations	Proposed solution does not exceed capacity limitation including future growth	Met at both locations
4. Energy Security - cost to achieve uninterruptable onsite energy generation	$	Installation provides estimate for onsite demand	Generated roadmap allows for 100 % onsite uninterruptable power generation for critical facilities at no additional cost	Met at both locations
5. Simple Payback (SPB) of proposed scenario compared to the Base Case	Years		15	Met at USMA, not met at PNSY
6. Planning cost SPB	Years	Projected energy cost savings and the ESTCP project budget	Roadmap planning costs will be recovered from energy savings within 1 year	Met at both locations

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4.0 FACILITY/SITE DESCRIPTION

NZP was demonstrated at two defense installations, the U.S. Military Academy (USMA) at West Point, NY, and the Portsmouth Naval Shipyard (PNSY), Kittery, ME.

4.1 THE U.S. MILITARY ACADEMY (USMA), WEST POINT

4.1.1 Site Location and Operations

The U.S. Military Academy (USMA), is located on the west bank of the Hudson River about 50 miles (80 km) north of New York City. The main campus and central installation area (cantonment area) total 1,800 acres (728 ha), composes only a portion of the nearly 16,000-acre (6,475 ha) reservation (Figure 4-1). The campus comprises approximately 700 buildings that occupy nearly 10 million sq. ft. (930,000 m^2) of gross floor area, more than 50% of which is concentrated in the central region. The campus has a central steam plant that operates year-round and provides heating and Domestic Hot Water (DHW) for the core campus area via a steam distribution system. From the 5.7 million sq. ft. (530,100 m^2) gross floor area in the central campus area and the south loop, about 5 million sq. ft. (465,000 m^2) are connected to the steam grid. The central plant has a steam generating capacity of 250,000 lb./hr. (250 Btu/min).

4.1.2 Site Conditions

The selected annual baseline was an average between 2010 and 2011 with the planning horizon from 2013 to 2020. Using a mean value as a synthetic baseline helps to prevent an unusually hot or cold year from skewing the results of a study. From the beginning of the project, it became clear that it would not be technically and financially feasible to meet the 2020 NZE goal on the entire installation (i.e., there is a lack of technical, human, and funding resources). Therefore, reasonable boundaries for an NZE area were established so that the goal would be achievable. The following criteria and logic were used in defining the preliminary NZE boundary:

- Density of Buildings. Selection of a densely-populated area with a high-energy demand would allow for lower costs in distribution modernization and lower distribution heat and cooling losses.
- Grid Connection. Buildings will be clustered by their connection to the thermal grid.
- USMA will maintain control over building energy use.
- USMA will set priorities for building stock modernization.

4.1.3 Boundaries of Analysis

The USMA community was divided into five clusters using the two heating grids and their possible enlargements as well as the density and usage of buildings as criteria for boundaries (Figure 4-1). Based on the above criteria, the central cluster of buildings was selected as the NZE study area. All buildings within this cluster are connected to the CEP and represent the major part of the installation’s energy use. In the near future, an additional barracks building will be constructed within this area and connected to the central plant, increasing the total number of buildings in this area to 45. Furthermore, most of potential funding for building modernization is planned for buildings located in this area.

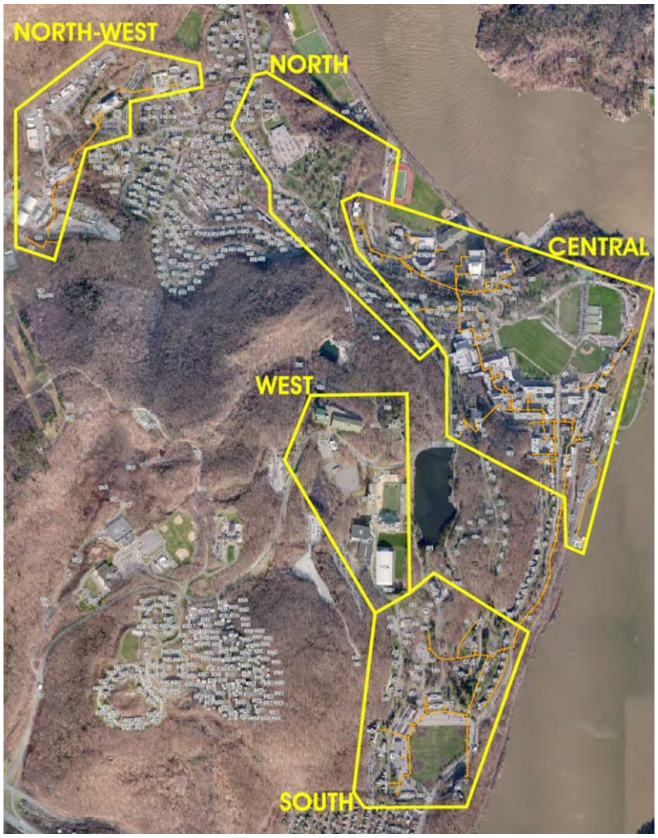

Figure 4-1. Site Map with Existing Heating Grids and Rough Cluster Boundaries.

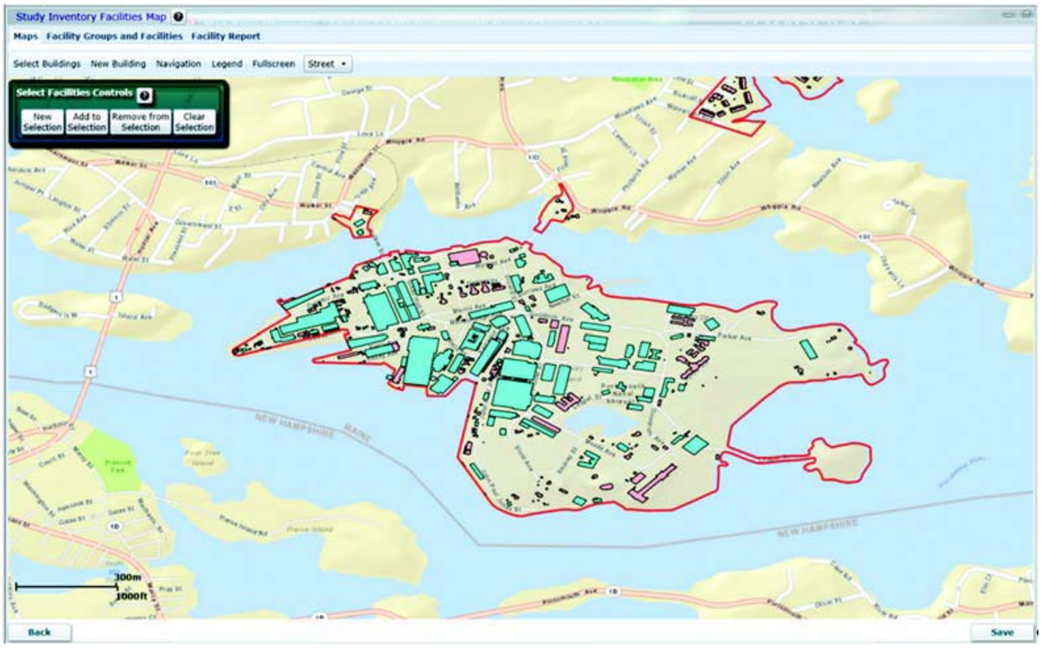

Figure 4-2. Layout of PNSY in the NZP Tool.

The 44 buildings included in the central area have a gross floor area of about 50% of the total gross floor area of the entire USMA. The USMA SRM budget is limited. According to information provided by the Directorate of Public Works (DPW), only a few buildings have a potential to be funded for major renovation. Also, several buildings that have steam heating systems will be converted to hot water heating system. These two categories of buildings were analyzed for cost efficient energy saving potential.

4.2 PORTSMOUTH NAVAL SHIPYARD (PNSY)

4.2.1 Site Location and Operations

PNSY, which was established in 1800, is located close to Kittery, ME, on Seavey's Island in the Piscataqua River, close to its outlet to the Atlantic Ocean. The shipyard has buildings and workshops, many of which are listed historical structures. It has three dry docks (DDs) and additional maintenance berths. Figure 4-2 shows the functional layout of the installation.

4.2.2 Site Conditions

PNSY has an existing CEP that supplies steam to most of the site and generates the bulk of the installation's electricity requirements. There is a single connection to the grid near the access bridge to the installation. The installation's current role is primarily the repair and refit of submarines. The study included 127 industrial and nonindustrial shipyard buildings.

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5.0 TEST DESIGN

5.1 CONCEPTUAL TEST DESIGN

5.1.1 Independent Variable

Net Zero Energy communities are achievable. Good planning can significantly affect the quality of the outcome (i.e., how close you can get to achieving energy goals), and the cost of implementation, operation and maintenance (O&M). Therefore, the application of NZP is considered to be an independent variable.

5.1.2 Dependent Variable(s)

NZP generates many different scenarios to meet an installation's energy goals. These scenarios have different first, replacement, operations and maintenance, and energy costs. These costs can be summarized as an annualized cost, which can be used as a dependent variable.

5.1.3 Controlled Variable(s)

The analysis was conducted within selected NZE Area boundaries. Energy goals (e.g., source energy use reduction, energy cost reduction, onsite generation capacity [energy security] and peak load limitations) were determined in consultation with each pilot installation and are fixed for the purpose of this demonstration project.

5.1.4 Hypothesis

The use of NZP can enable military installation master planners to achieve their energy goals cost effectively (Simple Payback [SPB] for implementation below 15 years and SPB of planning investment below 1 year), compared to a current base case scenario developed by the standard master planning process.

5.2 OPERATIONAL TESTING — USMA

5.2.1 Energy Objectives

USMA EMP was based on the need to meet a combination of energy objectives in a cost effective, balanced way.

5.2.2 Energy Efficiency Goals

By 2020, the site energy use on the installation will be 40% less than the 2011 baseline, including thermal energy supplied to the installation, and electrical energy purchased from the grid.

5.2.3 Supply Security Goals

The current level of energy reliability will be improved and onsite power generation capability will increase from the current 8.9 thousand British Thermal Unit (MBtu)/hr (2.6 MW) to at least 40.9 MBtu/hr (12 MW).

5.2.4 Fossil Fuel Reduction Goals

By 2020, the installation should strive for "zero fossil fuel based" energy use and a reduction in greenhouse gas (GHG) emissions from both onsite stationary sources (Scope 1) and purchased electricity (Scope 2).

5.2.5 USMA Energy Economics Goals

The net investments aimed at achieving energy goals will achieve an Internal Rate of Return (IRR) of at least 5%, which approaches twice the current return on 30-year U.S. Treasury Bonds.

5.2.6 USMA Baseline

The baseline is a snapshot of USMA's NZE Area energy profile (site and source energy) for the NZE boundary as an average of 2010 and 2011 in the following categories: (1) end uses, (2) building functions, (3) distribution losses on site, (4) steam network losses, (5) onsite electrical use, (6) conversion losses on site (gas turbines, boilers, and steam turbines), (7) off-site conversion and distribution losses, (8) purchased natural gas, and (9) purchased electricity.

5.2.7 USMA Energy End Use – Buildings Function

Forty-four buildings that currently exist in the NZE Area can be divided into 18 typical building types, each of which was modeled for energy use. The results of the model runs provided annual and peak energy use for the HVAC, lighting, DHW, and miscellaneous electrical systems for these buildings. The annual energy use values for each building were estimated by multiplying the energy use per unit of building area for each system by the specific building area. These total values were then compared and adjusted to the annual fuel use by the CEP and the peak heating demands on that plant.

5.2.8 USMA Conversion and Distribution Losses

The gas utility purchase records provided by USMA-DPW for the CEP for 2010 and 2011 state that the CEP consumed an average 5,005,500 ccf of natural gas, or 511,600 MMBtu (149,935 MWh) per year. The results of distribution loss analysis indicate that the 81,000 MMBtu per year in losses are due to pipe conduction losses, and condensate, steam, and other leaks in the current steam distribution system.

5.2.9 Base Case and Alternatives

After establishing the baseline, the Base Case and four potential scenarios were developed for USMA as the long-term energy use reduction solutions for the campus to meet energy goals. Alternatives were selected starting with a historic type of system used at the installation and its modification (district hot and chilled water system) using guidance set forth in a recent Army memorandum (EISA 2007), a decentralized solution, and a variety of options available from the NZP database. The criteria used to select these alternatives were total operating costs, LCCs, and sustainability.

- *Base Case*. The Base Case assumes that the existing situation described in the baseline will be changed only due to already planned projects.

- *Alternative 1*. Convert steam systems to hot water heating in buildings and decentralize the central boiler system.
- *Alternative 2*. Convert buildings to hot water heating and reuse existing central boilers to convert steam to hot water.
- *Alternative 3*. Convert buildings to hot water heating and provide a TriGen System using reciprocal engines to generate electricity and use waste heat to provide domestic water heating, winter heating, and summer cooling.
- *Alternative 4*. Convert buildings to hot water heating and provide a TriGen System using gas and steam turbines to generate electricity and use waste heat to provide domestic water heating, winter heating, and summer cooling.

5.2.10 Analysis of Results

Based on technical and economical merits, Alternative 3 is the most fitting selection, as it meets all energy goals (including the potential for NZE) and has the lowest LCC and an attractive return on investment with a simple payback of 10 years. For a detailed description of these alternatives, please refer to the final report document for this project.

5.2.11 Implementation Strategy

The complexity of the project with a significant construction budget of $130,430,694 requires its phased implementation. Based on discussions with DPW, the proposed Trigeneration Scenario (Alternative 3) is recommended to be implemented in the following order:

1. Install one 4 MW Combined Heat and Power (CHP) engine to meet infrastructure limitations.
2. Install absorption chillers in CEP.
3. Convert existing steam distribution system to HW and add chiller distribution piping.
4. Convert remaining buildings from steam-based to HW-based heating systems.
5. Install additional two 4 Megawatt (MW) CHP engine in CEP and upgrade CEP existing infrastructure to connect with main substation.
6. Install additional HW absorption chillers at two other locations.
7. Install additional emergency generators (if needed) to fill-in the capacity gap.
8. Construct Liquefied Natural Gas (LNG) station as an emergency backup for energy security as an option.
9. Construct syngas plant to replace natural gas (when the syngas price becomes cost competitive).

5.2.12 Modeling of USMA in Net Zero Planner

For the test at USMA, the SMEs did their analysis first, then the analysis was done using the NZP Tool so that the NZP team could test to see if similar results could be obtained. Both the SME team and the NZP team used an overlapping set of data, with the NZP team also requiring GIS data. Section 2 described the process in some detail, so this section will focus on key segments of the process.

5.2.12.1 Importing Facilities

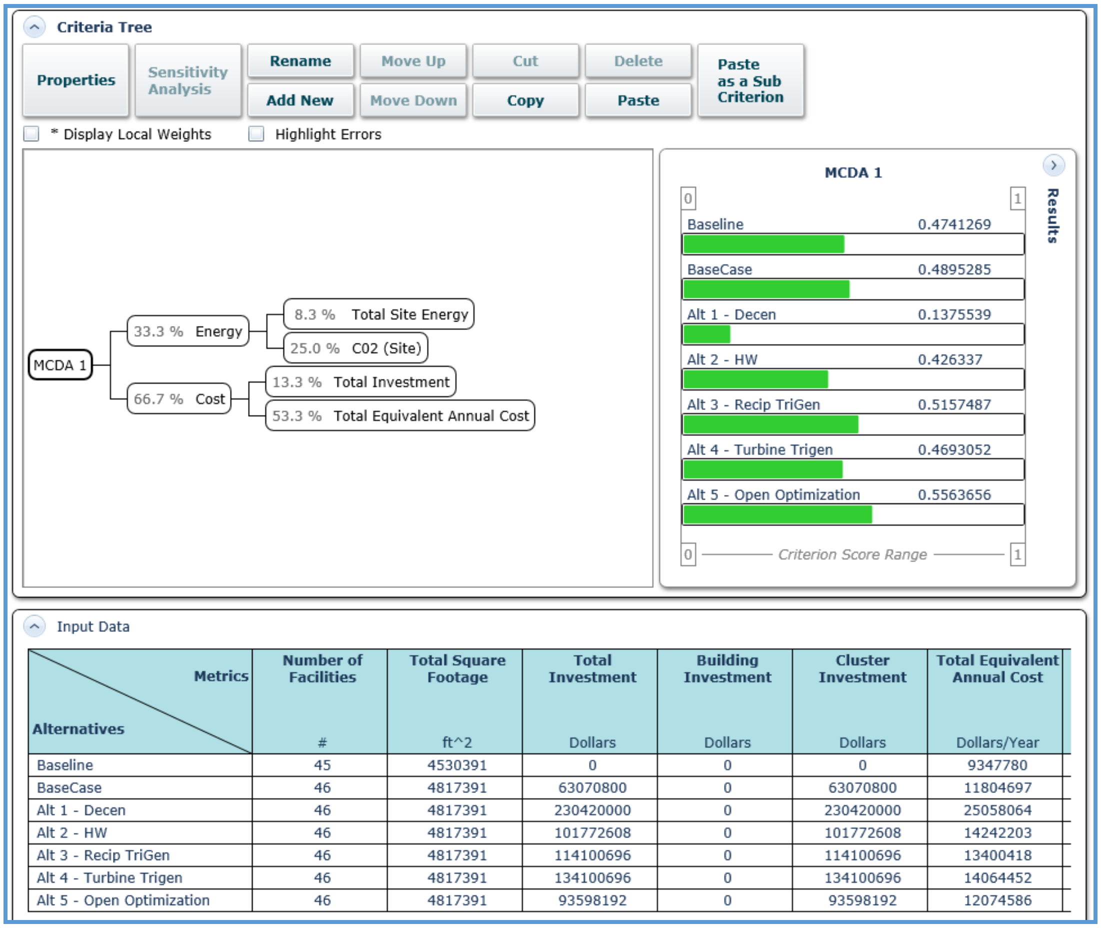
Facility data were imported from a Spatial Data Standards for Facilities, Infrastructure, and Environment (SDS/FIE) compliant GIS database [SDSFIE 2015], augmented by Real Property Inventory data from General Fund Enterprise Business System (GFEBS). One building was split into two for modeling purposes, so the NZP run has one more building than the SME run, but the same area. During modeling, a technique was developed to represent a deep energy retrofit (DER) of existing buildings. The EEM packages used by NZP represent existing buildings and new buildings differently. Existing buildings are generally limited in the extent to which EEM packages can be applied. New buildings represent a clean slate from a design point of view, with a larger number of EEM package options available. When a building goes through a DER, however, much more extensive EEM packages can be applied than with an existing building, especially with respect to the building's envelope. The NZP team developed a technique to address DER by marking existing buildings as "Demolish" and substituting a "Planned" building of the same type, but built to a modern standard in its place. In this way, a larger variety of EEMs are available and the NZP SME can assess the depth of the expected DER and choose appropriate EEMs.

5.2.12.2 Modeling and Optimizing the Baseline, Base Case, and Alternatives

The baseline was calibrated against the same energy data as the SMEs used, considering total installation bills, conversion efficiencies, and steam system losses. Once calibrated, a Base Case was created by running the standard sets for EEM packages against all the facility types as per the process described in Section 2 and selecting reasonable sets of EEMs for each type. These selected EEMS were used in all the alternatives considered.

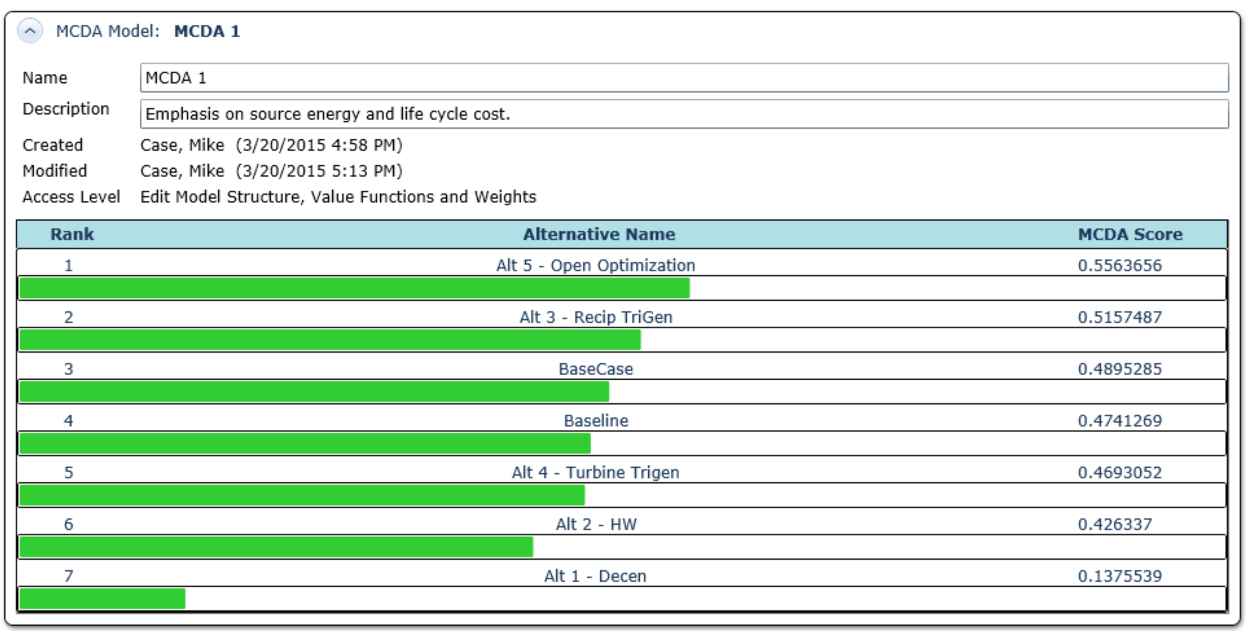
5.2.12.3 Modeling and Optimizing across the Installation

The facilities modeled within the Facility Loads section of NZP were incorporated into a single cluster. The 8,760 hours of simulation data for each facility group are scaled by conditioned area of each group and aggregated to create an 8,760-hour aggregate load that considers coincident loads, i.e., it calculates the coincident demand of the entire system. With quantitative results in hand, it is now possible to construct a decision model in NZP. Figure 5-1 shows a simple MCDA model that considers energy (site and CO_2 emissions) and cost (first investment cost and total equivalent annual cost). CO_2 emissions correlate roughly with source energy. A relatively higher weight is assigned to cost than to energy, reflecting the requirement that energy projects be life cycle cost effective. NZP shows the available quantitative metrics to the user while they are constructing the model. Figure 5-2 shows the rankings of the alternatives using the MCDA model. In the tradeoff between energy, greenhouse gases, and cost, it is illustrative that the Baseline and Base Case appear in the "middle of the pack." Open optimization is the clear winner, with decentralized heating the most expensive and largest user of source energy. If the model had been based on site energy alone without consideration of cost, the decentralized alternative would have taken preference.



Alternatives \ Metrics	Number of Facilities #	Total Square Footage ft^2	Total Investment Dollars	Building Investment Dollars	Cluster Investment Dollars	Total Equivalent Annual Cost Dollars/Year
Baseline	45	4530391	0	0	0	9347780
BaseCase	46	4817391	63070800	0	63070800	11804697
Alt 1 - Decen	46	4817391	230420000	0	230420000	25058064
Alt 2 - HW	46	4817391	101772608	0	101772608	14242203
Alt 3 - Recip TriGen	46	4817391	114100696	0	114100696	13400418
Alt 4 - Turbine Trigen	46	4817391	134100696	0	134100696	14064452
Alt 5 - Open Optimization	46	4817391	93598192	0	93598192	12074586

Figure 5-1. The MCDA Decision Model is Constructed from the NZP Model Output Data.



Rank	Alternative Name	MCDA Score
1	Alt 5 - Open Optimization	0.5563656
2	Alt 3 - Recip TriGen	0.5157487
3	BaseCase	0.4895285
4	Baseline	0.4741269
5	Alt 4 - Turbine Trigen	0.4693052
6	Alt 2 - HW	0.426337
7	Alt 1 - Decen	0.1375539

Figure 5-2. The MCDA Decision Model Results in a Ranked Ordering of Alternatives.

5.2.12.4 Discussion

USMA was the first installation test of NZP. There were several additional benefits observed by the NZP team in using the tool. First, the speed of calculations and rollup was much better in the tool than in the process employed by the SMEs. Second, once the models were created, it was considerably easier and less costly to make changes to the model, and then examine the results. The SME team required a good deal of time to coordinate results by passing spreadsheets back and forth. By contrast, NZP's ability to maintain, organize, and roll up the data made a change in the model relatively painless. The assembly of the SME report for USMA was both time consuming and expensive. This experience led the NZP team to create a module that will automatically generate reports from Microsoft Word templates, funded out of the NZP research program. This capability is expected to be available by the end of FY15 and will save 1 to 2 months of manually generating assessment documents.

5.3 OPERATIONAL TESTING —PNSY

5.3.1 Energy Objectives

The PNSY kickoff meeting identified strategic areas for energy objectives. Specific energy objectives were defined for each area and confirmed by the shipyard leadership.

5.3.2 Baseline

PNSY provided detailed usage and rate breakdowns for fiscal year 2010 (FY10) and FY11. Two-thirds of all energy purchases are ultimately used for heating in buildings, industrial processes, and berths and DDs; by far the largest part of that portion is used for the heating of buildings. Over three-quarters of the installation's energy costs are for natural gas, primarily to run the gas turbines (GT). Notice that the purchased electricity is ~9% of total energy purchases, but ~22% of the energy costs.

5.3.2.1 Baseline Site Energy Uses

Of the total 1,010,140 MMBtu (296,043 MWh) purchased by PNSY, 113,450 MMBtu (33,249 MWh), or 11%, is lost in boiler and turbine inefficiencies, leaving the balance of 896,700 MMBtu (262,797 MWh) for distribution around the shipyard. The inefficiencies assumptions are based on the manufacturers' specifications and input from the PNSY operating staff. Of this total onsite energy supply, 896,700 MMBtu (262,797 MWh), 64% is distributed as steam, 25% is electricity generated onsite by the two GTs, with the balance, or 10%, being electricity purchased from Central Maine Power. There is also a small amount or 0.4% propane and ~1% heating oil of additional fuels.

5.3.2.2 Baseline Source Energy Uses

The total source energy consumed by the shipyard is 1,257,000 MMBtu (368,500 MWh) per year. The estimated breakdown of the total source energy is summarized as follows: building and industrial processes at 29%, berths and DDs at 12%, onsite distribution at 21%, onsite conversion at 18%, and off-site conversion and distribution at 20%. Source energy is roughly equivalent to the total fuel needed to supply the shipyard, including that used by electricity generation and transmission supplied by the external grid. An estimated 59% of all this fuel used by PNSY is attributable to the generation and distribution of heat and electricity, both on and off the shipyard, of which 20% is grid-purchased electricity.

5.3.2.3 Baseline Energy Use — Buildings

The shipyard has 127 industrial and nonindustrial buildings, many of which, with minor exceptions, do not have metering. To estimate their energy needs, a modeling approach was used to estimate both the magnitude and type of energy use. The first step of the building modeling process is to select all buildings to be considered as a part of the installation's EMP and distribute them among different building types/categories. From a review of the site plans and site visit, there were four main usage types on site: office, residential, warehouse, and industrial. Industrial buildings on the site were categorized in a slightly different way. First, they were grouped by age, after which generalized models for warehouse and offices of an appropriate age were assigned to each industrial building. In addition to the energy end use from the normal building functions, the industrial buildings had an industrial process load added to them by the SME team.

Of the total 1,010,140 MMBtu (296,043 MWh) purchased by PNSY, only about 368,000 MMBtu (108,000 MWh), or 37%, is used for buildings and industrial process. Of that, more than half, 53%, is for space heating. Industrial processes are 8% of end use, about 3% of purchased energy, and were much less than expected by the intended function of this installation.

5.3.2.4 Baseline Energy Use — Berths and DDs

The steam and electricity system of the shipyard supplies the three DDs along with their associated berths. As with all other major end uses on the shipyard, there is no metering or similar monitoring data available. The following estimating approaches were used:

- *Steam*. The total delivery of steam to the DDs and berths was assumed to be the balance remaining after the network losses and the modeled requirements for heating buildings and industrial processes, i.e., 36,400 MMBtu (10,668 MWh) annually.
- *Electricity*. The total electricity use was derived from the balance of the remaining demand after subtracting distribution losses, building usage, and industrial process usage from the total purchases and onsite generation. Based on this approach, the baseline electricity usage is 115,100 MMBtu/yr. (33,720 MWh/yr.).

In summary, the berths and DDs consume about 17% of all the energy distributed on the installation.

5.3.2.5 Simulating Baseline Energy Use

The above assumptions for buildings, utilities, and process load calculations were the starting point for the SME approach and NZP Tool. The job server in the NZP Tool runs a program called "PARAMS," a parametric software tool that overlays the EnergyPlus building energy simulation software. The same energy simulation program was ultimately used for both methods, but the process to specify each of the models is quite different. The results indicate that the total energy answers are different, but relatively close between methods. For the larger building groups, industrial, warehouse, and office, the differences between the methods are small. Some of the smaller groups have more variance, but balance out in the total energy.

Even with the simplified parametric program input in the NZP Tool with different persons entering the installation data, the output data for each of the building categories show good overall comparison.

5.3.3 Base Case

The Base Case covers the energy used on the installation from present to the end of the study period in 2040 and assumes that the buildings and site would undergo business as usual. This generally assumes that the activity level would be unchanged and function of existing buildings would not change. Thus, annual DD steam use will increase by 14,420 MMBtu (4226 MWh) and electricity by 6031 MMBtu (1830 MWh), extrapolated from existing DD usage. The result is that steam use increases annually to 59,490 MMBtu (17,435 MWh) from 36,400 MMBtu (10,668 MWh) and electricity to 121,131 MMBtu (35,550 MWh) from 115,100 MMBtu (33,720 MWh). Both then remain constant through 2040.

5.3.3.1 Facility Level Optimization

The facility level optimization is the next step in the process after determining the Baseline and the Base Case to compare against. At the facility level, all the building EEM options are applied to each facility group. The NZP Tool saves substantial time when conducting studies through its ability to automatically apply packages of EEMs to facility types. Packages are put together by SMEs with experience in facility optimization and are organized by facility type and era of construction (e.g., built to ASHRAE 90.1-2007). The NZP Tool obtains the EEM package from the “PARAMS” server in an extensible markup language (XML) format and dynamically modifies the user interface to display them to the user. The NZP Tool displays packages of EEMs, such as lighting, high efficiency equipment, and airtightness (infiltration). Up to 12 different sets of packages might be applied, although there is no limit, and packages can depend on each other. The user can review the EEM parameters or accept the defaults for a first pass, coming back later to refine the EEMs and possibly select newer technology. At the end of the facility optimization step, the NZP Tool contains a dataset for each alternative with a full set of building load profiles. The user selects the EEM package based on the cost effectiveness, site criteria, DoD policy, and meeting the stated energy goals.

The assumptions for the EEMs are that the easier and less costly improvements may be done earlier on their own energy savings merit. The more extensive EEMs retrofits will be accomplished during a DER. DERs are done on the building for reasons other than for energy efficiency and then the incremental cost for energy improvements are only considered as justification for the building EEM. For PNSY, most of the buildings are old, and many are designated as historical and will need a deep retrofit in the near future. Since the building savings are not enough to meet the energy goals, additional optimization of the supply and distribution infrastructure was performed.

5.3.3.2 Energy Supply and Distribution Analysis Optimization

The next major step in the process is to define the appropriate supply and distribution alternatives for this installation, determined by SME experience, site visits, and discussions with site energy personnel. The supply and distribution analysis of PNSY was broken down into four different groups of buildings based on their current heating sources. The heating load for these groups are met by steam from the central plant, natural gas from a distributed network, propane with building-specific storage tanks, and fuel oil with building-specific storage tanks. This breakdown was chosen to best account for the existing network infrastructure, which transports the majority of the energy used on PNSY. This study focused on the energy sources for the first cluster, as these buildings use approximately 93% of PNSY’s total energy demand.

With the integrated building demand, supply and distribution scenarios were considered for the buildings connected to the existing steam network for comparative analysis and comparison to Baseline and Base Case. These scenarios are:

1. *Baseline*. This scenario models the building cluster as it exists today.
2. *Base Case*. This scenario models the building cluster as it would be with all planned building construction, renovation, and demolition.
3. *District Steam*. This scenario models the building cluster with a modern steam system.
4. *District HW and Spot Steam (District HW)*. The scenario models the building cluster with a modern HW system and spot steam generation to meet process load requirements.
5. *Decentralized*. This scenario models the building cluster with decentralized boilers/furnaces and spot steam generation to meet process load requirements.
6. *Net Zero Fossil Fuel*. This scenario models the building cluster with a modern HW system and finds the lowest equivalent annual cost equipment suite to meet net zero fossil fuel goals.

5.3.3.3 Supply and Distribution Analysis Results

Results from the Baseline and Base Case scenarios show the cost and usage that would be expected when the existing equipment is used with an optimal dispatch schedule. Though no investment costs are associated with these scenarios, they are among the costliest solutions on an annualized basis. These high annual costs are primarily the result of an aging and very inefficient steam network.

Additionally, maintenance and operations costs for the network topped $4.5 million for FY 2012. This has resulted in a very expensive and energy-intensive supply and distribution system. However, the electricity produced by the natural GT at the central plant has helped to significantly reduce PNSY’s source energy usage, when compared to using grid electricity and provided a secondary source of electricity for the installation. The district steam scenario would require an approximately $54.6 million investment (NZP Tool estimate) in a modern steam system and two reciprocating engines, but would be significantly less expensive than the Base Case on an annual basis.

The district HW scenario is very similar to the district steam scenario, but with a few key differences. This scenario would require an approximately $44 million investment (NZP Tool estimate) for a modern HW distribution network and the same two reciprocating engines used in the modern steam alternative. Switching to a HW network will require changing out some of the heat exchangers for buildings that currently distribute low-pressure steam. Spot steam generation will be required for the few remaining process-related loads. Both changes increase the investment cost of the scenario, but it remains significantly less costly than the modern district steam scenario. The lower operating temperatures of the system lead to lower conduction losses in the network and ultimately, lower costs of operation. Furthermore, this HW system can take advantage of all the waste heat generated by the natural gas reciprocating engines. This fact leads to the district HW scenario having lower source energy consumption and operating costs than the district steam scenario.

The decentralized scenario would meet the building heating loads for the buildings connected to the current steam system using individualized building boilers and would require an investment of approximately $41 million (NZP Tool estimate). However, this scenario does not provide the same site energy security as the central systems.

The Net Zero Fossil Fuel scenario finds the lowest equivalent annual cost solution to providing the heating, cooling, and electrical needs of the building cluster without netting any fossil fuel over the course of the year. In theory, this means that the installation can use fossil fuel, but must export power (generally renewably generated) off the installation to offset someone else's fossil fuel consumption. This analysis provides a rough estimate of the cost of attaining the net zero goals for PNSY. Finally, the solution lends itself well to having a resilient and highly redundant installation. The installation would be able to provide electricity from four different sources (grid, natural GT, diesel generators, and biomass-based steam turbines) and heating from four sources (natural gas, biogas, diesel/fuel oil, and biomass). This should allow the installation to maintain critical functions even under severe fuel supply restrictions.

5.3.3.4 Comparison of SME and NZP Tool Results

The SME group analyzed the same set of alternatives as for the NZP Tool, except the Net Zero Fossil Fuel scenario. The energy and investment costs results of the two groups have some differences, but the cost and energy ranking of the scenarios by both groups are nearly the same. The major differences in LCC between the SME group and the NZP Tool are determined by what is included in the Base Case finances.

The building loads and fuel usage for the scenarios are different. The baselines are close, but the SME process for applying EEMs is customized, while the NZP Tool applies standardized packages by facility group with customization of the input parameters for the installation. This leads to different and more conservative results than the SME process. The deviation between fuel usages starts to vary more after the building EEMs are applied beyond the Base Case scenario. However, most important is that the strategic decisions and rankings are maintained between the two processes.

Since the approaches by the SME group and NZP Tool are different in the way that building EEMs are applied and that observation and measurements are determined, the Base Case LCC numbers obtained by SME and from NZP Tool cannot be directly compared. Comparison of LCC numbers is invalid and should not be done because each individual analysis includes different Base Case values. The important aspect is that, with similar investments, both methodologies recommend the same strategic direction. The economic analysis by the SMEs was done by a proprietary spreadsheet method, while the NZP results were input into *Building Life Cycle Cost* (BLCC-NIST 2013) 5.3 software program from National Institute of Standards and Technology (NIST).

Note that currently the LCC analysis for the Net Zero Fossil Fuel case is not cost effective. Either the price of fuel will escalate faster than NIST predictions, or there will be a valuation of GHG or carbon tax to make these types of scenarios cost effective using government LCC procedures.

5.4 DISCUSSION

Modeling results at the building loads step in the process using the NZP tool were very close to those obtained using the SME approach, but required much less effort (in time and labor, and resulting labor costs). The reduction of the loads with the EEMs was not enough to meet the energy goals for the installation, which include energy security and carbon footprint reduction with source energy and GHG. Navy installations can purchase Renewable Energy Credits (RECs), but PNSY leadership has expressed a desire to *not* exercise that option to attain the targets.

The baseline analysis of the installation is always very insightful and allowed the analysis teams to quantify the magnitude of the steam distribution losses. It was fortunate that PNSY took this seriously and performed the dark factory test, and provided the data from the procedure.

The investment cost and energy usage results for both groups agreed within 10 to 20% for all the scenarios, despite the differences in the process used by each group. Furthermore, the energy usage and investment cost rankings were the same for both groups and ultimately resulted in the same recommendations to the installation.

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6.0 PERFORMANCE ASSESSMENT

The six performance objectives listed in Table 3-1 include:

1. Installation/campus-wide 55% source energy use
2. Energy cost reduction of 60% compared to Base Case
3. Projected electricity peak load below capacity limitation
4. Achieved energy security to satisfy 100% critical facilities power needs by onsite uninterruptable power generation
5. Not more than 15 years' simple payback of proposed best scenario compared to Base Case
6. Less than 1year planning costs recovery.

Table 6-1 lists the results of an analysis of the demonstration projects alongside the first five performance objectives, for comparison. These data show that performance parameters at the USMA NZE Area exceed the stated goals while source energy and energy cost reduction and SPB goals at PNSY have not been met. The main reason for not meeting these goals is that PNSY is the Navy industrial site and most of energy use is based on mission-related processes. Though process-related energy consumption can be reduced (e.g., by installation of energy efficient scaffolding and other process-related measures), the level of energy use reduction is limited.

For the project demonstration, "Objective 6 – Planning Cost Recovery," is the most critical. The success criterion for this objective was that the roadmap planning costs could be recovered from 1 year's energy savings.

This project has tested the cost effectiveness of using NZP Planner Tool compared to current best practices. The NZE Area selected for analysis at USMA, West Point included 45 buildings in 18 building categories (separated by building type and age). The PNSY NZE Area included 127 buildings in 22 building categories. The demonstration at both sites was conducted using two separate teams of experts with relevant experiences from the United States and around the world. This cost analysis assumed that data collection to develop a baseline would follow a similar process with and without use of the NZP Planner Tool, and would thus require the same effort and the same level of funding.

ERDC's contract with the PERTAN Company provided SME support for USMA and PNSY projects in development of building analysis and district/cluster analysis. The part of the budget dedicated to energy analysis of different scenarios at the USMA NZE Area was about $130K, and at PNSY was about $100K. Both projects involved unique, historic buildings, which required more effort in their analysis.

Table 6-1. Cost Summary for Analysis Using the SME and NZP.

Installation	Number of Buildings	Number of Building Categories	Time Required		Cost of Data Analysis Using, $1000	
			SME	NZP	SME	NZP
USMA, West Point	45	11	5 months	5 wks.	167	52
PNSY	127	22	4 months	5 wks.	130	52

Based on the data collected by the ERDC researchers and SMEs before energy analysis and used in both approaches (with and without NZE Planner Tool), the second approach required data setup, building level modeling, calibration, and the modeling and iteration of generation and distribution scenarios. This work, which was performed by the ERDC team, took about 3 weeks and cost about $50k, when using the NZP Tool (this cost is further discussed in the next section).

Thus, the use of NZP Tool reduces the time required for the analysis and the analysis cost to only a fraction (~33%) of that of the alternative current best practice (Table 6-1).

Besides its use on pilot projects funded by ESTCP program, NZP is currently being used at Fort Leonard Wood, Missouri, and several other installations. After the ESTCP project is finalized, ERDC is planning to conduct technology transfer to Federal and private sector teams that provide support to DoD installations. All DoD installations can therefore benefit from adaptation of the demonstrated concept and the software package. In addition, a pilot program is being developed at the USACE Fort Worth District to provide usage of the NZP Tool to provide the SCP overlay for the required ADPs at installations. In 2015, 23 SCPs were being developed using the NZP Tool with teams provided by the district office. If this pilot program is successful, and a Standard Procedure is developed to implement the NZP Tool in the ADP/SCP process, then this can be scaled up to other districts across the Army.

7.0 COST ASSESSMENT

This section discusses the costs associated with performing an Energy Master Plan (EMP) and compares those costs with and without the use of the Net Zero Planner (NZP) Tool.

7.1 COST MODEL

Table 7-1 briefly summarizes the cost elements involved in developing an EMP using the NZP Tool (the cost of performing an EMP without the tool will be taken as the contractor costs for the work performed on PNSY and the West Point Military Academy [WPMA]). The cost estimates provided apply to studies with ~100-200 buildings. The total cost will increase or decrease with the total number of buildings for communities that are much larger or smaller than the range provided. Many of the cost elements (related to the NZP Tool) were not charged to the ESTCP project (such as server costs and training costs) because a separate research project was paying for these costs. However, the labor costs were significantly higher as the overall process was being studied and performed by contractors and the NZP Tool team in parallel. The elements needed to perform an EMP using the NZP Tool are:

1. *Labor*: This cost element is for the team that performs the EMP for the installation. This team can comprise as little as two people (depending on the size of the installation or area). The work takes an average of five full time equivalent weeks for both members, but could be spread over a longer period. The work includes:
    a. Discussion of the goals for the study with installation personnel.
    b. Gathering general site data (GIS, metering data, real property data, utility rate schedules, etc.) and preparing the study.
    c. Travel to the site to confirm the electronic data and perform building and central plant walkthroughs.
    d. Correcting and supplementing the study information based on the site visit.
    e. Follow-up with the installation personnel and further corrections.
    f. Generation of potential energy alternatives for the installation.
    g. Travel to the second site visit to communicate the results.
    h. Follow-up with installation personnel and final report. The costs associated with this element scale with the size and complexity of the installation or area.
2. *Travel*: This cost element is straightforward and scales with the locality costs and travel distance/complexity.
3. *Server Costs*: This cost element is related to the cost of hosting the NZP Tool site and providing computational power (servers) to perform the analysis. This is a set cost for each installation or area.
4. *Training*: This cost element is associated with training new NZP Tool users and should be thought of as an average training cost per project. To date, training has been performed in a classroom setting for groups of 15-25 people and during site visits for 1-2 users as a final preparation for independent use of the tool. The training shows users how to perform all the analysis tasks in the tool, provides a basic understanding of the energy master planning process, and gives the user some rule of thumb type knowledge to help guide them in the field. About five of the classroom-type training events have been held to date, but this will become standard as the tool continues to see increased use. This element is a fixed cost for each installation or area.

5. *Maintenance and Feature Development*: This cost element is associated with the computer scientists and research engineers that continue to develop and improve the NZP Tool. They play a critical support role and can continue to reduce the amount of manual work that must be done to complete the EMP. This cost element is fixed for each installation or area.
6. *Organizational Overhead*: This cost element is associated with the organization that supports the workers that perform the EMP and the maintenance and development personnel. This cost element is fixed for each installation or area.

Table 7-1. Cost Model for Use of the NZP Tool on an Installation.

Cost Element*	Description	Estimated Costs
Labor	Labor for SMEs that perform the study on the installation or an ADP within the installation.	$130/hr for 5 weeks (40 hrs.*5) x 2 People = $52,000
Travel	Travel costs to installation (2 trips for the team).	$2,000/trip * 2 people x 2 trips = $8,000
Server Costs	Costs associated with owning and operating (or renting) the servers that run the NZP Tool.	$7,000
Training	Costs associated with training additional engineers to use the tool. This training may involve travel to a site to learn from an experienced group.	$5,000
Maintenance and Feature Development	Additional labor for research team that continues development and fixes bugs with the NZP Tool. This also covers importing and adjusting the installation's geospatial data.	$16,000
Subtotal		$88,000
Organizational Overhead	Overhead costs for support personnel, building, etc.	~40% add-on = $35,200
Grand total		$123,200

*Costs are estimated to apply the NZE tool for one installation.

7.2 COST DRIVERS

The main cost drivers associated with the EPM are the size and complexity of the installation or area.

The size (in terms of area and buildings considered) adds to the labor involved in performing a site walkthrough and confirming data for the existing building stock. This factor generally increases the cost of study linearly as the size increases. The costs listed in Table 7-1 are average values for an installation or area with ~100-200 buildings.

The complexity of a site can add additional cost and time to a study as well. The complexity of the site generally refers to energy usages that are unknown (things like the large steam process loads for manufacturing or repair found at Portsmouth) or issues that have not been handled before in the process. These complexities require a break from the established data collection and verification process and sometime require additional work to the NZP Tool. However, now that many studies have been performed in the tool (there will be greater than 30 studies completed in the tool by the end of 2015), most of the issues and complexities that arise in studies have been studied and solved.

7.3 COST ANALYSIS AND COMPARISON

This section compares the cost of completing an EMP using the Net Zero Planner (NZP) Tool to the cost of completing the same plan without the tool. The initial work that led to installation Baseline and Base Case cost approximately $150k for each contractor group/installation. This cost covered all the initial data collection (including utility bills, utility rate schedules, building data collected through walkthroughs, central plant and distribution network data, etc.), customer interactions (to determine energy goals, installation priorities and preferences, etc.), and the analysis required to develop models of the current status of the installation (baseline) and the business as usual situation (Base Case). Most of these steps require roughly the same amount of time and work when performed by a contractor group or by using the NZP Tool, but the workload of the analysis step is significantly reduced when using the NZP Tool. This workload reduction drops the cost of developing the Baseline and Base Case when using the NZP Tool to ~$75k. The benefits of using the NZP Tool are even greater when developing energy alternatives for the installation.

The cost of adding contractor-developed energy alternatives to the Baseline and Base Case analysis was ~$130k for the USMA, West Point study. This cost was based on the size (44 buildings and ~4.4 million sq. ft. of conditioned area) and complexity of the installation. The complexity in the USMA, West Point study was primarily due to the historic nature of the buildings (limiting the potential for exterior renovations), the existing steam system (with vastly different pressure/temperatures being delivered to different buildings and seasonal shutoffs), and the seasonal nature of the energy usage for some of the buildings (due to the university type of usage).

The cost of adding contractor-developed energy alternatives to the Baseline and Base Case analysis was ~$167k for the Portsmouth Naval Shipyard study. Again, the cost was based size (127 buildings and ~3.2 million sq. ft. of conditioned area) and complexity of the installation. The complexity in the Portsmouth Naval Shipyard study was primarily due to the unknown size of the steam and electrical process loads related to the repair of naval equipment, the poor condition of the steam distribution lines (sections of these lines become completely submerged in the salt water at various times of the year), the security division of the installation (restricting certain changes within this region), and the number and variety of buildings in the installation.

The cost of adding energy alternatives to the Baseline and Base Case analysis using the NZP Tool is about $50k (resulting in the total cost of ~$125k). This dramatic reduction in the cost is due to the automation of the data handling associated with producing these alternatives. For example, changes to the building models and applying EEMs can be made with just a few mouse clicks and quickly applied to entire groups of similar builds. These changes are then automatically recalculated so the results are available to the user within minutes. The contractor group would need to go into each building model to make specific changes to multiple parameters, then rerun all the building models, and finally sum up all the results for all the building types. This is a significant effort when done manually for any large number of buildings and the sheer volume of manual data handling increases the chance for errors.

Additionally, new alternatives can be built from existing alternatives using a single copy button. This functionally allows the transfer of all study information (weather, climate, utility rate structures, etc.), building data, and central plant infrastructure data to be copied over for the next alternative.

The user can then make small changes (for example, adding the potential to use cogeneration equipment at the central plant) to the alternative, and have updated results for the new scenario within 15-30 minutes. This is a vast reduction in the amount of time that is needed to develop additional alternatives.

In the end, the approximate cost of the contractor-led EMPs was ~300k for each installation. Compared with the ~125k listed in Table 7-1, this amounts to a savings of over half.

A fee of ~$100k was charged to installations to use the tool to develop 23 EPMs that are being performed during the FY15 (about 50% complete at the writing of this report). The cost is slightly lower than the cost of the work done for USMA, West Point and Portsmouth Naval Shipyard due to the reduced size and complexity of these studies and the increased efficiency of the process, due to the work done here. The energy master planning process was further developed since it was used for USMA, West Point and Portsmouth. It is now called a Sustainability Component Plan (SCP) and is performed after the completion of an ADP to add energy guidance to the planning process. The SCP currently provides energy usage data for the Baseline, Base Case, Better Case, and Best Case alternatives. The Better Case provides energy usage data for each building (and the cumulative area) if it was renovated to the current ASHRAE standard. The Best Case provides energy usage data for each building (and the cumulative area) with additional EEMs applied (to the greatest extent possible). The SCP report provides a list of the measures applied to each building, the changes in building parameters for each (changes in infiltration, lighting density, etc.), a planning level cost for the improvements (assuming they are performed during a major renovation). Further, the report captures the buildings slated for demolition and planned buildings into the analysis and provides short-term, long-term, and potential capacity phases for the construction and energy usage (a summary that shows the status of all buildings at each of the three phases). Finally, the report provides a scoping study on potential “installation scale” energy technologies that have significant energy and/or cost saving potential for the area. These technologies include district energy systems and renewable energy systems.

7.4 CONCLUSIONS

This work concludes that the use of the NZP Tool dramatically reduces the cost of developing an Energy Master Plan for an installation. The tool itself helps guide the energy master planning process and leads to a more repeatable and controlled development of the plan. This process helps to reduce or eliminate some of the common biases of engineers and planners who develop the EMP (especially biases toward or against certain technologies). Finally, the NZP provides an energy model of the installation that is accessible by the installation staff for further updating and use in identifying, developing, and reporting on current and future energy projects.

8.0 IMPLEMENTATION ISSUES

Among major end-user concerns are:

1. Installation-wide energy master planning requires setting numerous energy goals (site and source energy efficiency, energy security, limitations of power and natural gas utilities, etc.) upfront. Setting realistic and quantifiable goals presents a challenge to most of installations.
2. Complexity of NZE solutions and the need to follow them through.
3. Significant first costs of their implementation.
4. Significant effort required to manage the transition process.

USACE or DPW develop installation Master Plans either in-house, or by subcontracting to private sector companies. The NZP Tool can be used either by in-house personnel or by contractors. While the limited number of USACE energy master planners can be trained to apply energy master planning concepts and to use the tool, use of NZP Tool by contractors will require a broader program to train all potential contractors involved in energy master planning. Trainees will need to have "*.mil" Internet access and Common Access Cards (CACs).

Throughout this project at both installations, SMEs used the results of this work to refine both the process and the NZP Tool. The energy planning process was refined and several steps were added, e.g., the introduction of the Baseline and the Base Case, which are now clearly defined and integrated into the process and the Tool. During the projects, it became apparent that there was a need to determine how to calibrate the Baseline; thus, inputting data from energy meters became an important step in the beginning of the study. During the projects, (especially while executing USMA and PNSY projects, and reviewing the different approaches taken by each SME group that did the comparative validating analysis), it became clear that there was a need to frame goals that establish the type of study that needs to be done, i.e., a planning or pre-engineering analysis.

The process alignment also helped define the customer for the NZP Tool, and who at the installation would be the user of the program. Two groups of users were determined each with different output requirements. The Installation Master Planner's is a group that has a need to use the NZP Tool to quantify and provide a Sustainability Component Plan to overlay their building EPMs. The other identified user is the installation energy manager, who has a need for help in identifying and coordinating the sequence of energy projects, which requires a pre-engineering assessment.

Many user interface changes were made throughout the program to facilitate the process, to make it easier for the user to enter data, and to help determine what information needed to be provided for output reports. The current version of the NZP Tool increases the speed and efficiency of the EMP process significantly by providing repeatability and reduction of human error in the tedious tasks required in the process. This eases the burden of doing repeated tasks for both the experienced and less skilled users, and allows access to many additional users typically under the guidance of SMEs. The NZP Tool still allows the creative user to customize the tool as needed to meet the specific needs of an individual installation. The process provides the accessibility to the analysis by less skilled people. All users benefit from the simplification of repeated tasks, which "lowers the bar" for making changes and redoing analyses dynamically.

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ESTCP Office
4800 Mark Center Drive
Suite 17D08
Alexandria, VA 22350-3605
(571) 372-6565 (Phone)
E-mail: estcp@estcp.org
www.serdp-estcp.org